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Fire Blight of Pear and Apple

H. E. Thomas and K. G. Parker

Bacterial exudate on pear branch

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FIRE BLIGHT OF PEAR AND APPLE

H. E. Thomas and K. G. Parker [1]

The rapid extension of pear growing in the past fifteen years has resulted in the necessity for increasingly intensive methods of culture on the part of individual pear growers and of pear-growing communities. It is scarcely necessary to point out that any program which looks toward greater economy in the growing of pears must involve, as an important part, the understanding and the continuous practice of fire-blight control. Notwithstanding the fact that fire blight has been studied intensively for a period of approximately fifty years, a considerable amount of new information has resulted from the work of the past ten years. This bulletin aims to bring together the more important facts, new and old, which have come out of the work in this and other States.

PLANTS AFFECTED

More than eighty species and a large number of varieties of plants are now known to be affected by fire blight. Most of these are rather closely related to pear and apple, but occasionally such distantly related sorts as walnut (Smith, 1931) and persimmon (Thomas and Thomas, 1931) are found to be susceptible. There is evidence, moreover, that the list of susceptible plants is yet to be considerably extended. This is indicated by the following observations and experiments on species of hawthorn most of which are presumably indigenous to central New York.[2]

Apparently only two of the numerous species of Crataegus are on record as subject to fire blight—*C. oxyacantha* (Arthur, 1885) and *C. crusgalli* (Reed, 1914)—and the evidence for the latter of these is observational only. During 1930 and 1931 a blight was seen on several other species in Tompkins County exhibiting symptoms which were in all essential features those of fire blight. During the summer of 1931 the fire-blight organism was isolated from natural infections on *C. crusgalli, C. monogyna, C. oxyacantha,* and *C. punctata.* In the case of *C. oxyacantha,* the common English hawthorn, the germ was obtained from a canker which had survived the preceding winter. *C. monogyna,* an English hawthorn very similar to *C. oxyacantha,* appears to be about equal to that species in susceptibility to blight and was severely blighted in several cases observed. *C. punctata,* a very common species, was moderately blighted in several localities in and around Ithaca, as were also *C. crusgalli*

[1] The writers are indebted to R. L. Nelson, of Clyde, New York, in whose orchard (referred to as the Nelson orchard) various observations and experiments were made from 1926 to 1931. During the season of 1927 the work in the Nelson orchard was done by W. F. Crosier, to whom the writers are grateful for material drawn from his unpublished report.

[2] The writers are indebted to Dr. K. M. Wiegand, of the Department of Botany, New York State College of Agriculture, for the identification of the species of Crataegus.

and *C. succulenta* in one instance each. Infection was obtained by artificial inoculation[3] on shoots of *C. crusgalli, C. monogyna,* and *C. succulenta,* and on fruits of *C. arnoldiana, C. mollis,* and *C. punctata.*

While it does not seem desirable to list in detail all the species of different genera known to be susceptible, it may be well to summarize them here.

Amelanchier (1 species)	Service berry
Chaenomeles (2 species)	Flowering and Chinese quinces
Cotoneaster (8 species)	
Crataegus (7 species)	Hawthorn
Cydonia (1 species)	Quince
Diospyros (1 species)	Persimmon
Eriobotrya (1 species)	Loquat
Fragaria (2[?] species)	Strawberry
Heteromeles (1 species)	Toyon
Juglans (7 species)	Walnut
Mespilus (1 species)	Medlar
Photinia (1 species)	
Prunus (13 species)	Flowering almond, apricot, cherry, plum, prune
Pyracantha (5 species)	Firethorn
Pyrus (36 species)	Pear and apple, wild and cultivated
Raphiolepis (1 species)	
Rosa (2 species)	Rose
Sorbus (2 species)	Mountain ash
Spiraea (1 species)	Vanhoutte spirea

Summaries of the earlier work on this phase of the fire-blight problem are presented by Snow (1922), Rosen and Groves (1928), and Pierstorff (1931). More recently, additions to the list have been made by Groves (1931), Smith (1931), and Thomas and Thomas (1931).

While mountain ash is often listed as susceptible to fire blight, successful infection experiments do not seem to have been made on this plant. On July 21, 1931, 20 fruits and 5 shoots were inoculated on plants of European mountain ash (*Sorbus aucuparia*) at Ithaca. Only very slight killing resulted, on a single shoot. However, the other shoots and the fruits were more mature than is desirable for infection experiments. In view of the fact that Racicot (1931) has isolated the fire-blight organism from mountain ash, it is probable that the disease noted on these plants by earlier workers was the common fire blight.

Notwithstanding this impressive list of susceptible plants, fire blight is seldom seen in New York on plants other than pear, apple, quince, and hawthorn.

[3] From 10 to 90 inoculations were made on each of the species tested. These included fruits, terminal shoots, and small branches (at base of side branches). Attempts to produce infection in plants of the following species were unsuccessful: *C. beata, C. Brainerdii, C. calpodendron, C. coccinea, C. filipes, C. Holmesiana, C. macracantha, C. macrosperma, C. phaenopyrum, C. pruinosa.* These negative results are by no means final, since many of the inoculations were made in late June and July after the principal period of terminal growth had passed. It is concluded, however, that these species are relatively resistant if not immune. All inoculations were made in the field, with the exception of some of those on *C. succulenta* which were made on potted plants in the greenhouse.

VARIETAL SUSCEPTIBILITY

PEAR

All the varieties of pears grown commercially in North America are subject to fire blight, and none of the better varieties possesses even a high degree of resistance. The varieties Clapp Favorite, Bartlett, Flemish Beauty, Bosc, and Howell are highly susceptible, while Seckel, Anjou, Duchess, Comice, and Winter Nelis are somewhat less so. In general the oriental pears, and some of their hybrids such as Kieffer, Le Conte, and Garber, are more or less resistant, though not infrequently some of these may be entirely destroyed by blight. Reimer (1925), in Oregon, has introduced and studied large numbers of oriental species and varieties chiefly for use as stocks on which to grow the European varieties. None seems to have been found as yet which can be confidently recommended.

APPLE

In apples, and to some extent in pears (Reimer, 1925), there is a marked difference in varieties as regards the susceptibility of blossom spurs and twigs on the one hand, and of trunks and larger branches on the other. For example, the McIntosh and Tompkins King varieties may show about the same amount of blossom and twig infection, and yet very few cankers are formed on the trunks and branches of McIntosh while those of Tompkins King are highly susceptible. In general, the varieties Alexander, Esopus Spitzenberg, Fall Pippin, Tompkins King, Transcendent (crab), Wagener, and Yellow Transparent are particularly susceptible to fire blight, and Rhode Island Greening, Twenty Ounce, and Wealthy are moderately susceptible. Baldwin, Ben Davis, Delicious, Gravenstein, McIntosh, Northern Spy, and Oldenburg show a considerable degree of resistance.

THE DISEASE

NAMES

Many names have been applied to this disease in its various aspects. It may be designated according to the plant affected—as *pear blight, quince blight,* and the like—or according to the part of the plant which is injured — as, for example, *blossom blight, twig blight, collar blight.* The original name, *fire blight,* has been widely used and is adopted here since it is descriptive of the most characteristic symptom—a blackening of twigs, flowers, and foliage as though they had been swept by fire.

SYMPTOMS AND SIGNS

It may seem at first thought that the symptoms of fire blight are so definite and obvious as to require little discussion. This is by no means the case. In fact, one of the commonest causes of failure in blight-eradication work is the inability of the operator to find the blight infections and to distinguish them clearly from other types of injury.

On blossoms and fruit spurs

The first new blight infections to be seen in the spring are usually on the blossoms. These at first become water-soaked in appearance

(from ten days to three weeks after blossoming), and frequently exude small, grayish white, viscous drops which later become brown. The blossoms rapidly become shriveled and brown (in the apple) or black (in the pear). The blossoms alone may be killed, but usually the neighboring leaves and spur are involved and a canker is frequently seen on the supporting branch (figure 1). Not uncommonly some of the fruits of a diseased cluster may at first escape infection and later become invaded through the pedicel from the affected cluster base.

FIGURE 1. A BLIGHTED BLOSSOM SPUR OF APPLE, WITH A SMALL CANKER AT THE BASE

On leaves

Leaves usually become invaded by the blight germ (indirectly) through the petiole from the diseased twigs to which they are attached. In such

cases the leaf is discolored from the base upward, first along the midvein and the large lateral veins, until finally the entire leaf blade has become brown or black. In exceptional seasons and situations, direct infection of the leaf blade may take place (Heald, 1927), producing rather large, irregularly shaped spots in which the organism is usually checked before the entire leaf is blighted.

On twigs

Following blossom infection, the terminal shoots and the suckers in the center and at the base of the tree are commonly seen to develop symptoms, at first near the tips, where in the earliest stages only a slight wilting may be seen. Ooze may be exuded from the stems and the larger veins of the leaves before any appreciable discoloration of the tissues has taken place. Following these early symptoms rapidly and progressively, the stem becomes water-soaked and then brown or black, and the leaves collapse (figure 2). The dead leaves remain attached long after the unaffected leaves have fallen, serving as flags in the inspection of blighted trees. Here again a canker is frequently found at the base of the infected shoot.

On smooth branches

Cankers on the branches are usually initiated around the base of a blighted fruit spur or shoot, and this fact is of invaluable aid in finding them. The canker in its early stages is irregularly circular or oval in outline, and rarely, if ever, involves long, narrow strips of bark along one side of the branch as is frequently the case with winter injury. Also in contrast with winter injury, blighted bark remains firmly attached to the wood long after it is dead. The organism spreads first in the outer bark, giving it a water-soaked appearance which is usually visible externally on smooth bark. Later the bark becomes somewhat darker than the adjacent living bark. The surface of the bark usually remains smooth for a considerable time, whereas the bark in the common black-rot canker (perhaps the most likely to be confused with fire blight) is roughened, owing to the formation of the fruiting bodies of the fungus in the outer bark. Not uncommonly an older blight canker may be invaded by the fungus of the black-rot canker or by other fungi, thus increasing the difficulty of diagnosis. When the blight canker becomes inactive, the dead bark is usually separated from the living by a crack which commonly marks the limits of a dormant or a permanently inactivated canker. When it is present, the grayish to brown exudate (shown in the illustration on the front cover of this bulletin) is a most reliable sign of an active blight canker. The most consistent symptom of an active canker is found in the characteristic reddish brown lines and mottling within the bark (Plate I) which follow the earlier water-soaked aspect. This mottling is almost invariably seen in some part of an active fire-blight canker and is not known to occur in any other type of canker on pear or apple.

On trunks and larger branches

The most difficult form of fire blight to find, and at the same time the most dangerous, is the canker which forms in the roughened scaly bark

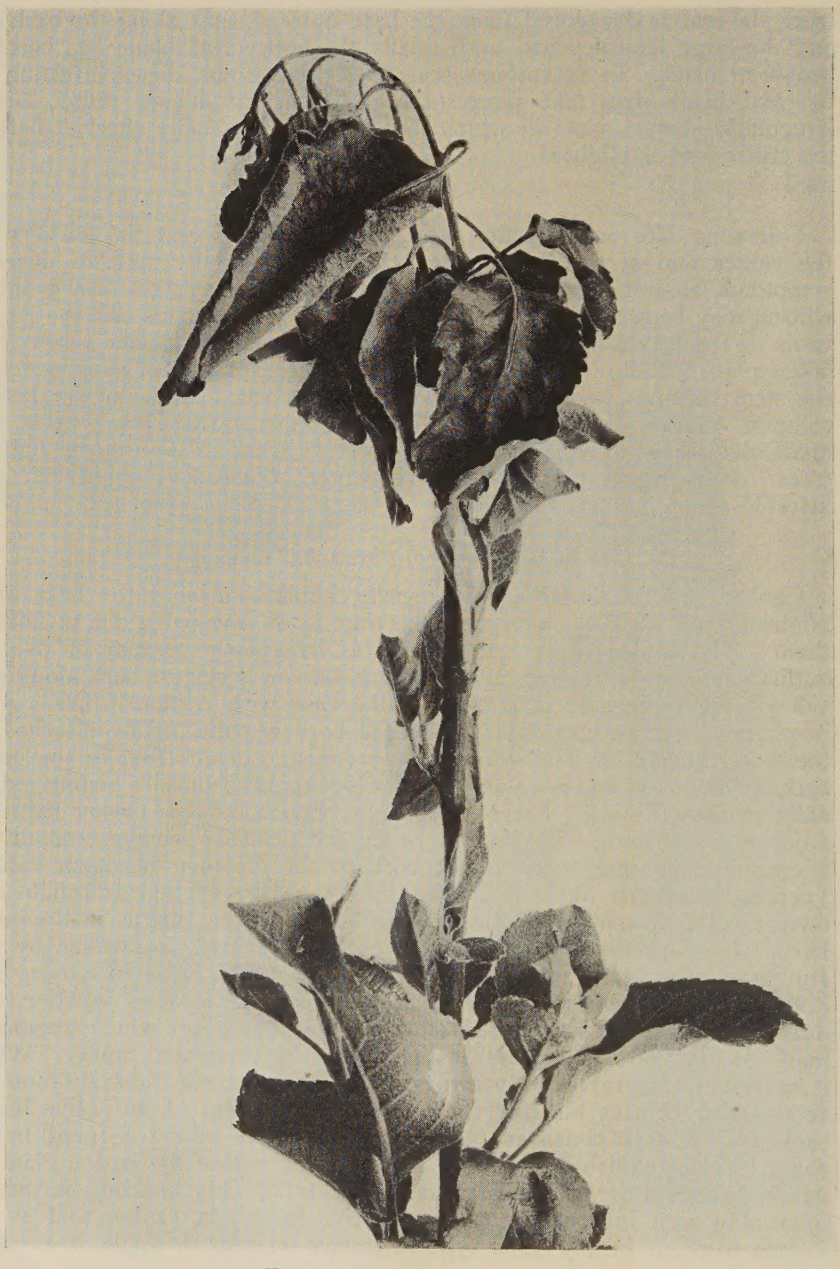

FIGURE 2. TWIG BLIGHT OF APPLE

ACTIVE CANKER ON TOMPKINS KING APPLE

The surface bark has been cut away in order to show the characteristic reddish color in the active parts of the canker, as contrasted with the dead, brown bark in the center, in which the organism is no longer active

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of the trunks and larger branches of older trees (figures 3 and 4). Not infrequently such cankers may spread actively for weeks or months with no external evidence of disease. Eventually the bacterial exudate will usually appear or the canker will spread to a younger branch where the symptoms may be seen. However, this often happens too late to permit of saving the tree. Fortunately the organism usually enters these old parts through blighted shoots which remain attached and mark the center of the infection.

FIGURE 3. A CANKER IN ROUGH BARK ON A LARGE APPLE BRANCH (SEE FIGURE 4)

FIGURE 4. THE BRANCH SHOWN IN FIGURE 3 WITH THE BARK CUT AWAY TO SHOW THE CANKER

The natural roughening and cracking of the bark on the trunks and branches of older trees is sometimes mistaken for fire-blight cankers, but it may be distinguished from these by the normal light color of the living bark beneath.

OVERWINTERING

The causal organism of fire blight (*Bacillus amylovorus*) is resistant to freezing at temperatures far below any that occur in nature (Pierstorff, 1931). It is rather sensitive to direct sunlight and to drying when not protected by the gelatinous matrix which accompanies it in the exudate from blighted plant tissues (Stewart, 1913 a; Hotson, 1916; Brooks,

1926). On the other hand, the exudate when kept continuously dry in the laboratory may still contain living organisms after more than two years (Pierstorff, 1931). Fortunately, in the orchard the exudate becomes disintegrated during the winter, and several attempts to obtain the organism from fragments of such exudate in late winter have been unsuccessful.

Similarly, the organism has been found to survive for a short time under natural conditions in association with honey in the beehive (Gossard and Walton, 1922), and for a much longer time (55 days, Thomas, 1930) on honeycomb in the laboratory. There is not specific proof, however, that the organism survives the winter in the beehive. On the contrary, observations in orchards, and the work of Gossard and Walton (1922) as well as unpublished experiments by the junior writer, indicate that this does not occur.

That the organism does not survive in the soil is strongly indicated by the fact that penetration into the roots seldom, if ever, seems to take place except through parts above ground. Waite (1896) was unable to obtain the bacteria from orchard soil, and no record has been found of the organism having been isolated from naturally infested soil. Arthur (1887) reported that the germs grew on soil extract (presumably in the absence of competing organisms). One of the present writers has recovered the organism after 64 days from soil which was first steamed and then artificially infested with the organism and kept at 25° C. However, it was not found in unsterilized soil which was similarly infested and exposed out of doors from December 9, 1922, to April 16, 1923. In various laboratory tests the writers have obtained a considerable number of bacterial organisms, from soil and other sources, which strongly inhibit the growth of the fire-blight bacteria in cultures. This factor of antagonism among competing organisms doubtless plays an important part in the failure of the blight organism to survive in orchard soil.

It is now well established that the principal seat of overwintering bacteria is in the living tissues near the margins of cankers on trunks and larger branches of pear and apple, and to a lesser extent on certain related plants (Sackett, 1911; Brooks, 1926; Nixon, 1927; Tullis, 1929). To be sure, it has been repeatedly shown that twigs and branches less than one-half inch in diameter may bear hold-over cankers (Sackett, 1911; Stewart, 1913 a; Brooks, 1926; Miller, 1929; Tullis, 1929; Pierstorff, 1931). This mode of survival of the germs is by no means to be ignored. For example, in central and western New York, at least occasional overwintering cankers on twigs three-eighths inch or less in diameter were found by Pierstorff (1931) and the writers in five of the past nine years (1923 to 1931). In two of these years such cankers were found in some abundance; in the other years they were seen rarely or not at all. Even when the organism has survived the winter in small twigs, it has been the observation of the writers that the resumption of activity is usually delayed until after the critical period of blossom time. On the other hand, oozing from large hold-over cankers has been seen as early as twenty days before pears (Bartletts) were in full bloom.

DISSEMINATION

The movement of the blight organism over great distances is apparently infrequent, as is evidenced by the present limited range of the disease outside of North America. This seems remarkable in view of the fact that the disease has been known in the eastern United States for approximately one hundred and fifty years. The work of McLarty (1927) should be of interest to growers of fruit for export. This author finds that a small percentage of fruits which are inoculated on the tree do not develop external symptoms until after several weeks in storage.

Dissemination from hold-over cankers to blossoms

By all odds, the widest dissemination of the blight organism within the orchard, and from orchard to orchard, takes place at blossom time. The source of the bacteria (hold-over cankers) for the inoculation of the first blossoms has already been discussed. The transfer of the organism from the hold-over cankers to the first blossoms is a purely mechanical process and may take place in a number of ways, some of which are doubtless still unknown.

Waite (1901) states that "flies and wasps and other insects swarm on the exuding sap," and Stewart (1913 a) observed that the tarnished plant-bug "frequently visited the sweet, gummy exudation on infected trees." Certain kinds of aphids (Brooks, 1926, and observations by the writers), ants (Jones, 1914, and the writers), flies (Stewart and Leonard, 1916, Jones, 1914, and the writers), and click beetles (Jones, 1914) have been observed to feed on oozing cankers, and all of these insects may be found on the blossom clusters of pear or apple at or near blossom time. Moreover, direct experimental evidence of the transmission of fire blight from oozing cankers to blossoms has been obtained with aphids by Tullis (1929), and with ants and flies by the junior writer.

Apparently the honeybee has never been observed to visit the hold-over cankers, and it seems probable that this seldom if ever occurs. On April 19, 1931, and again on April 23, oozing cankers were placed beside a hive in an apiary at Ithaca. The bees showed no interest whatever in the exudate, even when numbers of them were placed directly on the cankers. During the course of several hours spent in observing oozing cankers in 1929, 1930, and 1931, not a single honeybee was seen to approach the ooze, although the bees were present in considerable numbers in the orchards under observation.

The splashing of rain has been found by various workers (Miller, 1929, McClintock, 1931, and the junior writer) to be an additional means of spreading the organism from hold-over cankers to the first blossoms, and, indeed, has been assumed by some workers, on insufficient grounds, to be the chief agency in the spread of the organism at blossom time (Gossard and Walton, 1922; Miller, 1929).

Dissemination during the blossoming period

It is during the blossoming period proper[4] that the most rapid and serious spread of the fire-blight germs takes place. For more than thirty years the fact has been established (Waite, 1901) that the insects which

[4] One should not be misled by the fact that the symptoms of blight are usually not seen in the blossoms until one to three weeks after the period of full bloom.

visit the open flowers spread the organism from blossom to blossom. It is necessary only to visit an orchard in blossom on a bright, warm day to be impressed by the potentialities of this means of dissemination. Frequently, in addition to the bees of various kinds, other species of insects are active in the blossoms in large numbers. Waite (1901) counted 40 species visiting pear blossoms, and he leaves the impression that there were many others. In a survey of orchards in western New York and the Hudson River Valley in the spring of 1931, the Department of Entomology of Cornell University found more than 200 species of insects visiting the blossoms of apple trees.

The honeybee has naturally received particular attention in studies bearing on the spread of the fire-blight bacteria. Gossard and Walton (1922) were able to obtain the organism from the mouth parts of bees and from the honey in a naturally infested hive. The organism has been recovered also from artificially infested honey after periods of several weeks (McLarty, 1923; Thomas, 1930). It seems probable, therefore, that the bee not only spreads the organism from blossom to blossom, but also carries it into the hive, where other bees may become contaminated. It is possible, furthermore, that the germ may be carried with the hive from one orchard district to another when bees are shipped for use in pollinating fruit trees. Rosen (1930) reports having "isolated the fire blight pathogen from beehive material gathered throughout the summer, winter, and early spring" under the peculiar conditions prevailing in the Ozarks of Arkansas. However, specific evidence in support of this statement is wanting.

Several workers in more recent years have expressed the view that rain is an important agent in the spread of the organism from blossom to blossom, and even to twigs (Gossard and Walton, 1922; Miller, 1929; Tullis, 1929). However, the experimental evidence presented by most workers, and particularly that obtained by Pierstorff (1931) and the junior writer in New York, can more reasonably be interpreted on the ground that insects carry the blight organism from blossom to blossom, from tree to tree, and from orchard to orchard.

It is true that moisture in the soil and in the atmosphere seems to favor the production of exudate from cankers, and the power of the organism to establish itself and develop in the tree (Heald, 1927; Brooks, 1926; Miller, 1929; Tullis, 1929).[5] But this is aside from the question of how the organism is transported from place to place.

The distance over which the blight organism may be spread from a given hold-over source will obviously vary with the season, the insect population, and other factors. In severe epiphytotics all the trees of an orchard may be about equally affected by blight, while in milder cases only those trees near the hold-over cankers are likely to become blighted. The diagram presented as figure 5 is of interest as bearing on both the distance and the manner of spread of the bacteria in a year of little blight. Three sides of the diagram (top, right, and bottom) represent the margins of a small block of pear trees. All except one or two of the trees represented here are of the variety Clapp Favorite. Four centers of blossom infection

[5] The illustration on the front cover shows the exudate on an active pear canker kept over night in a moist atmosphere.

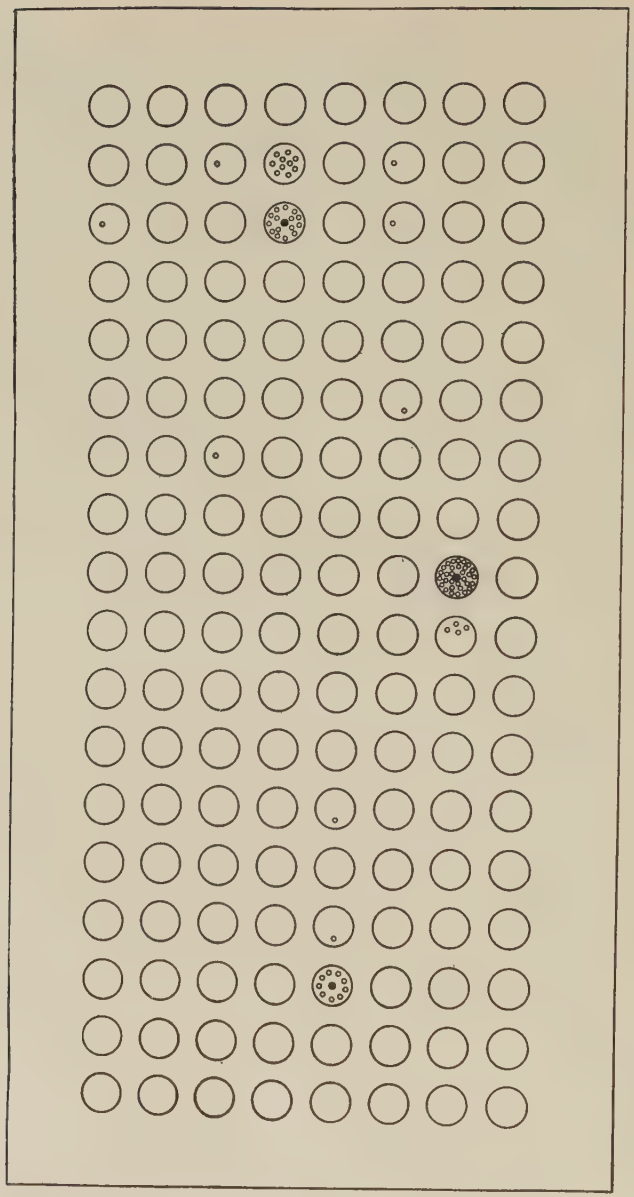

FIGURE 5. BLOSSOM-SPUR INFECTION IN A BLOCK OF PEARS, WAYNE COUNTY, 1929

Solid black circles mark hold-over cankers; open circles represent infected blossom spurs

developed in this block in 1929. For one of these, in the part of the block not shown, the source of primary inoculum was not determined with certainty. For the foci which are shown, the location of the hold-over canker and the total number of infected blossom spurs are indicated. In two of these (the upper and the lower) the infected blossoms on the trees bearing the hold-over cankers were mostly below the canker, while in the third they were above the source of inoculum or elsewhere in the tree. The blossoming period was rainy and cool, inhibiting extensive activity of insects, and was followed by a low yield of fruit. It is concluded from this and from similar instances noted in 1927 and 1928, as well as from direct observations on insect activity and weather conditions at blossom time, that (a) in seasons of limited insect activity the distances over which the organism may be spread are surprisingly short, and (b) even in such an extreme case as that cited above, the probability that rain is an agency of dissemination may be questioned for a considerable part of the infection.

In contrast to the foregoing may be cited a part of the principal block of pears in the Nelson orchard, where approximately 65 per cent of a comparable number of trees (144) developed blossom blight in 1930. No hold-over canker was found in this entire block of about 1100 trees in 1930, and only one in 1929. Hold-over cankers were found, however, in a neighboring farm about 200 yards from the corner of the block in which the above trees were located. It is noteworthy that the heaviest infection in the entire Nelson orchard in 1930 was in this area nearest the outside source of inoculum. On the other hand, there is no certain evidence of any relation between the blight in the Nelson orchard and that in the more remote neighboring plantings.

Dissemination after the blossoming period

While the prevalence of fire blight for the season is usually determined largely at blossom time, there may be a very serious increase of the disease during early and middle summer as a result of the activities of a number of sucking insects. These rarely if ever disseminate the organism so widely as do the pollinating insects, but, on the other hand, they are sometimes active locally over a much longer period. The following have been shown by experiment to be capable of inoculating the shoots of pear or apple: green apple aphis, *Aphis pomi* (Stewart, 1913 a); tarnished plant-bug, *Lygus pratensis* (Stewart, 1913 b); grain aphis, *Aphis avenae,* and leaf hopper, *Empoasca mali* (Burrill, 1915); *Adelphocoris rapidus, Campylomma verbasci, Orthotylus flavosparsus,* and *Poeciloscytus basalis* (Stewart and Leonard, 1915); *Plagiognathus politus* (Stewart and Leonard, 1916). Notable among these in New York orchards are the aphids on the apple and the tarnished plant-bugs on the pear. Each of these may be found, however, on both pear and apple.

A striking example of the relation of aphis (*Aphis pomi*) infestation to the occurrence of fire blight was recorded in the Nelson pear orchard at Clyde, New York, in 1927 (table 1). Aphids were present in at least small numbers in the orchard throughout the period from June 20 to

TABLE 1. NUMBER OF TREES FROM WHICH BLIGHTED SPURS AND TERMINALS WERE REMOVED FROM A BLOCK OF 1190 TREES DURING THREE PERIODS CHOSEN WITH REFERENCE TO APHIS INFESTATION

(Nelson orchard, 1927)

Period	First	Second	Third
Date	June 1 to July 15	July 15 to August 25	August 25 to September 20
Number of trees	22	270	20

August 10, and were present in large numbers during the period from July 4 to July 20. The dates shown in the table mark the limits of the periods during which the infections were removed, and are of course later than those which indicate the prevalence of the insects in the orchard. Although blighted blossom spurs are represented in the figures, as well as terminal shoots, the number of affected trees is nevertheless seen to reach a sharp peak during the period of greatest aphis activity. Such a relation between aphis infestation and fire blight appears to be common in apples, but much less so in pears, where aphids do not usually appear in such large numbers as was the case in this instance.

CONTROL

Pear growing, like other branches of agriculture, is steadily becoming a more specialized industry. Unfortunate though it may be, the amateur and inexpert grower finds in consequence a diminishing opportunity. Not only may he fail to grow the crop successfully or profitably, but his plantings will frequently prove a distinct menace to neighboring orchards. The situation in regard to apples, in many orchards of the State, is less critical but otherwise comparable.

Although some fruit growers in the State have successfully combated fire blight for many years (Whetzel and Stewart, 1909), the best known methods for blight control have been, and still are, tedious and difficult, resulting so frequently in failure that competent men have been led to question their efficacy. For this and other reasons, the writers have taken the standard control program into a commercial pear orchard (the Nelson orchard) for five successive seasons, with two main objectives in mind: first, a demonstration of the effectiveness of the program and of its cost under conditions which are defined; and second, the improvement or adaptation of existent methods of control.

The Nelson orchard, located at Clyde in Wayne County, New York, consists of five blocks totaling about 30 acres. In a total of approximately 3000 pear trees, some 2300 are of bearing age, ranging in 1927 from eleven to fifteen years old. The number of trees of different varieties has varied somewhat, owing to removal and replanting; but in 1929 there were 1507 Bartlett, 926 Kieffer, 476 Seckel, and 123 Clapp Favorite trees. The orchard is in sod, and when the work was begun the trees varied in vigor from poor to good. Drainage and the addition of fertilizers have since brought all the trees to a very satisfactory state of vigor. Four of the blocks are bordered on at least one side by apples, but, with the exception

of a few trees of the Tompkins King variety, the apples do not seem to have complicated the problem of blight control in the pears. The nearest sources of inoculum outside the farm are, respectively, about one-eighth, one-third, and one-half mile distant from the nearest block of the Nelson orchard. From the records of the number of infections removed from each tree in the orchard, it is evident that in 1930 a considerable part of the infection resulted from inoculum carried in from the first source mentioned.

None of the years during which this orchard has been under observation may be considered one of severe epiphytotic over the State, but blight was severe locally in western New York in 1930 and 1931.

In table 2 a summary is given of the number of trees, branches, blossom spurs, and terminals removed from the pear trees in the Nelson orchard during each year of the five-years period 1927 to 1931 inclusive. Some eradication work was done in the orchard in 1926, but no record of this has been preserved except that 39 trees were removed in October of that year. It will be noted that since 1928 the loss of entire trees, and even of larger branches, has been relatively small despite the fact that a considerable number of infections have appeared in the orchard each year except in 1929. It may be inferred, on the other hand, that the orchard will quickly revert to a severely blighted condition if less intensive control measures are adopted.

TABLE 2. INFECTIONS REMOVED FROM NELSON ORCHARD, AND COST PER BEARING TREE

Year	Number of trees removed	Number of branches 2 inches or more in diameter removed	Number of branches ⅜ to 2 inches in diameter removed	Number of blossom spurs and terminals removed	Cost per bearing tree (cents)
1927	41	58	403	3,290	18.5
1928	21	47	140	263	11.1
1929	2	0	10	18	2.1
1930	3	18	483	2,185	4.5
1931	11	30	576	1,655	4.9

The cost of the work is calculated on the basis of 50 cents an hour for the time actually used in eradication. By way of comparison, it is estimated that the cost of materials and labor for a single spray application in this orchard is about 6 cents per bearing tree.

Still more satisfactory results were obtained by similar methods in a small planting of pear trees at Wolcott, New York, which in 1929 contained 143 Bartlett and 16 Clapp Favorite trees, all of bearing age. In that year 11 trees and 16 large branches were removed because of blight. Although the trees are maintained in a condition of good vigor, no subsequent infection was found in 1929, 1930, or 1931. The nearest known source of inoculum in other plantings is about one and one-half miles distant.

It should be pointed out that the work was done by men with a considerable degree of special training. A man unfamiliar with fire blight is

of little value in the orchard except under very close supervision, and may even increase the loss by indiscriminate cutting and by spreading the blight organism (figures 6 and 7). The growers who are successful in combat-

FIGURE 6. VITAL PART OF A PEAR TREE SAVED BY TIMELY REMOVAL OF CANKER

ing fire blight have either familiarized themselves with the details of control work or employed one or more men who are primarily if not exclusively engaged in that work. The latter practice is of course feasible only with larger acreages. A competent man should be able to handle at least 50 acres of pears under average orchard conditions.

PRINCIPAL CONTROL MEASURES

In selecting an orchard site for the planting of susceptible trees, it is desirable that the grower should consider possible outside sources of the blight organism over which he has no control. The hazards are lessened by avoiding the planting of combinations such as pear, apple, and quince, which prolong the blossoming period. One should particularly avoid odd varieties which blossom slightly earlier than those which are to be the chief feature of the orchard. With apples, the danger of hold-over blight may be greatly reduced by omitting such susceptible varieties as Alexander, Esopus Spitzenburg, Wagener, Tompkins King, Fall Pippin, and Yellow Transparent. With pears, none of the commercial varieties is sufficiently

FIGURE 7. A BARTLETT TREE CUT BEYOND HOPE OF RECOVERY, WITH BLIGHT STILL SPREADING

resistant to influence markedly the choice for planting. More or less resistant pear stocks have been tested extensively in the Pacific Coast States, but none has as yet been found to be desirable in all respects.

A distinct advantage is found in maintaining under one management an acreage sufficient to employ one or more operators for full time in blight control.

The common practice of reducing the vigor of trees by withholding nitrogenous fertilizers is of value in reducing blight, but the resulting benefit is more than offset by the accompanying reduction in yield and injury to the trees by other agencies. It is inferred that a quickly available fertilizer is preferable in this connection to a slowly available one.

It is extremely important that every possible hold-over canker be removed from the orchard and from the immediate neighborhood before blossom time. This may be done at any time during the dormant season. All smaller branches, and larger branches which are more than half girdled by cankers, are best removed altogether. The manner of cutting small cankers on large branches is illustrated in figure 8. If all cut surfaces

FIGURE 8. METHOD OF CUTTING A DORMANT CANKER (CUTTING HALF COMPLETED)

are exposed, it is not necessary to apply a germicide to wounds made during the winter. The question of whether small blighted twigs may be safely left in the tree is often a perplexing one. It has been the observation of the writers that overwintering of the blight germ in small twigs of the more resistant varieties of apples is rare. When trees of such varieties are present in large numbers in the orchard, a question arises as to the economy of removing the terminal shoots that are blighted in only

a few inches of the tip. In trees of susceptible varieties of apples and of all commercial varieties of pears, it is unsafe to leave any blighted part in the orchard.

Spraying with bordeaux mixture just before or during blossoming has caused some reduction in blight in certain experiments (Stevens and others, 1917; McCue, 1917; Reimer, 1928; McCown, 1929), but in others it has been of no apparent benefit (Miller, 1929; McLarty, 1931). This method deserves further study.

Next in importance to the removal of overwintering blight infections, is the prompt removal or treatment of all new infections during the weeks that follow the blossoming period. Continuous effort should be made to free the trunks and the larger branches from blossom spurs and shoots before these become infected. Frequent systematic inspections of all susceptible trees in the orchard are indispensable during this period. If the infected blossoms are found in the earliest stages, the spurs can usually be broken off before the organism has invaded the bark of the supporting branch. Infected shoots, twigs, and small branches should be cut off at least a foot below the lowest symptom of disease. Cankers on larger branches may be removed in a manner similar to that illustrated in figure 8 for dormant cankers; but on more susceptible trees the cut must be made 6 inches or more beyond the visible margin of the canker. Wounds made during this period should be disinfected with a good germicide. The writers prefer a solution of 1 part each of bichloride of mercury and cyanide of mercury in 500 parts of water. This solution (Reimer, 1918) has been used by the writers for several years with satisfactory results, and in comparative tests has proved superior to bichloride of mercury alone.

In the treatment of smaller cankers on larger branches during the growing season, it is highly desirable that a solution be found which may check the advance of the organism when applied to the uncut surface of the bark. A method based on this principle would have certain obvious advantages. Cankers could be treated with less labor and at greater speed than by the surgical method. There would be less injury to sound bark and much less spread of the organism at the time of treatment.[6] A solution of zinc chloride for the surface treatment of cankers has been introduced into California pear orchards by Day (1930) and is now in wide use in that State. One of the present writers (Parker) has made a considerable number of experiments in an effort to devise or adapt a solution for use in New York orchards. Some experiments have been made with zinc chloride, and a larger number with cadmium-sulfate solutions. Encouraging results have been obtained, but none of the solutions has as yet been sufficiently tested to be offered for general use.

Finally, it is desired to reemphasize the fact that successful control of fire blight must involve not only the trees in the grower's orchard but all the susceptible plants in the neighborhood. The necessity for cooperation among neighbors in this regard is, in fact, so urgent as to have called forth legislative action in several States.

[6] In one block of mixed pears at Ithaca, more than 50 per cent of 143 cankers examined in September, 1930, centered around points at which earlier cuts had been made.

SUMMARY

In the present publication an attempt is made to bring together the essential facts necessary to the study of fire blight by the fruit grower.

Five species of Crataegus (hawthorn) are added to the list of susceptible plants.

Fair to good control of fire blight has been obtained in a commercial pear orchard in western New York over a five-years period, at an average annual cost scarcely greater than that of a single spray application in the same orchard.

REFERENCES CITED

ARTHUR, J. C. Pear blight. *In* Report of the Botanist. New York [Geneva] Agr. Exp. Sta. Ann. rept **3** (1884) : 357–367. 1885.

———— Pear blight. *In* Report of the Botanist. New York [Geneva] Agr. Exp. Sta. Ann. rept. **5** (1886) : 275–289, 300–315. 1887.

BROOKS, A. N. Studies of the epidemiology and control of fireblight of apple. Phytopath. **16** : 665–696. 1926.

BURRILL, A. C. Insect control important in checking fire blight. Phytopath **5** : 343–347. 1915.

DAY, LEONARD H. Zinc chloride treatment for pear blight cankers. Univ. California Coll. Agr., Agr. Ext. Service. Circ. 45 : 1–13. 1930.

GOSSARD, H. A., AND WALTON, R. C. Dissemination of fire blight. Ohio Agr. Exp. Sta. Bul. 357 : 81–126. 1922.

GROVES, A. B. Natural fire-blight infections on *Spiraea vanhouttei*. Phytopath. **21** : 89–91. 1931.

HEALD, FREDERICK D. Leaf invasions by *Bacillus amylovorus*. Northwest sci. **1** : 76–79. 1927.

HOTSON, J. W. The longevity of *Bacillus amylovorus* under field conditions. Phytopath. **6** : 400–408. 1916.

JONES, B. J. The natural modes of distribution of pear blight in California. California State Com. Hort. Monthly bul. **3** : 505–511. 1914.

MCCLINTOCK, J. A. The relation of canker treatment to fire-blight control. Phytopath. **21** : 901–906. 1931.

MCCOWN, MONROE. Bordeaux spray in the control of fire blight of apple. Phytopath. **19** : 285–293. 1929.

MCCUE, C. A. Pear blight. Peninsula Hort. Soc. Trans. **30** : 51–55. 1917.

MCLARTY, H. R. Report of the Dominion Field Laboratory of Plant Pathology, Summerland, B. C. Canada Agr. Dept. Report of the Dominion Botanist **1922** : 64–74. 1923.

———— Report of the Dominion Field Laboratory of Plant Pathology, Summerland, B. C. Canada Agr. Dept. Report of the Dominion Botanist **1926**: 132–141. 1927.

———— Report of the Dominion Plant Pathological Laboratory, Summerland, B. C. Canada Agr. Dept. Report of the Dominion Botanist **1929**: 119–132. 1931.

MILLER, P. W. Studies of fire blight of apple in Wisconsin. Journ. agr. research **39**: 579–621. 1929.

NIXON, E. L. The migration of *Bacillus amylovorus* in apple tissue and its effects on the host cells. Pennsylvania State Coll. Agr. Exp. Sta. Bul. 212: 1–16. 1927.

PIERSTORFF, A. L. Studies on the fire-blight organism, *Bacillus amylovorus*. Cornell Univ. Agr. Exp. Sta. Memoir 136: 1–53. 1931.

RACICOT, H. N. Fire blight investigations in western Quebec. Canada Agr. Dept. Report of the Dominion Botanist **1930**: 115. 1931.

REED, GEORGE M. An unusual outbreak of apple blossom blight. Phytopath. **4**: 27–30. 1914.

REIMER, F. C. A new disinfectant for pear blight. California Com. Hort. Monthly bul. **7**: 562–565. 1918.

———— Blight resistance in pears and characteristics of pear species and stocks. Oregon Agr. Coll. Exp. Sta. Bul. 214: 1–99. 1925.

———— Pear blight control. Better fruit 22^{11}: 9–10, 28. 1928.

ROSEN, H. R. Overwintering of the fire blight pathogen, *Bacillus amylovorus,* within the beehive. Science **72**: 301–302. 1930.

ROSEN, H. R., AND GROVES, A. B. Studies on fire blight: host range. Journ. agr. research **37**: 493–505. 1928.

SACKETT, WALTER G. Hold-over blight in the pear. Colorado Agr. Coll. Agr. Exp. Sta. Bul. 177: 1–8. 1911.

SMITH, CLAYTON O. Pathogenicity of *Bacillus amylovorus* on species of Juglans. Phytopath. **21**: 219–223. 1931.

SNOW, LAETITIA M. A new host for the fire blight organism, *Bacillus amylovorus*. Phytopath. **12**: 517–524. 1922.

STEVENS, F. L., RUTH, W. A., PELTIER, G. L., AND MALLOCH, J. R. Observations on pear blight in Illinois. (Abstract.) Phytopath. **7**: 75. 1917.

STEWART, V. B. The fire blight disease in nursery stock. Cornell Univ. Agr. Exp. Sta. Bul. 329: 313–372. 1913 a.

———— The importance of the tarnished plant bug in the dissemination of fire blight in nursery stock. Phytopath. **3**: 273–276. 1913 b.

STEWART, V. B., AND LEONARD, M. D. The rôle of sucking insects in the dissemination of fire blight bacteria. Phytopath. **5**: 117–123. 1915.

———— Further studies in the rôle of insects in the dissemination of fire blight bacteria. Phytopath. **6**: 152–158. 1916.

THOMAS, H. E. The longevity of *Bacillus amylovorus* (Burr.) Trev. in association with honey. Science **72**: 634. 1930.

THOMAS, H. E., AND THOMAS, H. E. Plants affected by fire blight. Phytopath. **21**: 425–435. 1931.

TULLIS, E. C. Studies on the overwintering and modes of infection of the fire blight organism. Michigan State Coll. Agr. Exp. Sta. Tech. bul. 97: 1–32. 1929.

WAITE, M. B. The cause and prevention of pear blight. U. S. Agr. Dept. Yearbook **1895**: 295–300. 1896.

————. The relation of bees to the orchard. Nat. Bee-Keepers Assn. Proc. **32**: 70–73. 1901.

WHETZEL, H. H., AND STEWART, V. B. Fire blight of pears, apples, quinces, etc. Cornell Univ. Agr. Exp. Sta. Bul. 272: 29–51. 1909.